COMPARATIVE ANALYSIS OF HYBRID STABILIZATION METHODS IN THE TREATMENT OF BURST FRACTURES OF THE VERTEBRAL BODIES ASSOCIATED WITH OSTEOPOROSIS

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Objective. To perform comparative analysis of posterior stabilization methods combined with cement vertebroplasty and osteoplasty with deproteinized bone allograft in the treatment of uncomplicated burst fractures of the vertebral bodies associated with osteoporosis.
Material and Methods. The study was a retrospective analysis. Two groups of patients were formed, inclusion and exclusion criteria were determined. The follow-up period was 12 months. The magnitude of kyphosis correction according to the Cobb method, the magnitude of residual postoperative kyphotic deformity, its recurrence in the long term postoperative period, and the length of transpedicular fixation were assessed. Sagittal balance parameters and subjective assessments of the patient's condition were not evaluated.
Results. With a statistically significant difference, it can be said that the main predictors of recurrence of local kyphosis, incomplete correction of deformity and increased pain syndrome are the level of injury (T12 vertebra), the degree of initial kyphotic deformity, incomplete achievement of its correction after surgery (>10°), and the value of T-criterion according to densitometry. The length of fixation does not affect the loss of correction and recurrence of kyphosis, however it may correlate with the severity of osteoporosis.
Conclusions. When comparing posterior stabilization methods in combination with cement vertebroplasty or osteoplasty, there was no statistical difference in clinical and radiological outcomes.
Key Words: burst fractures, osteoporosis, hybrid stabilizaion, vertebroplasty, osteoplasty, kyphosis.
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Surgical treatment of vertebral fractures in the elderly is widespread [1] due to the technique of posterior stabilization, which is characterized by minimal trauma and a positive primary effect. However, due to the axial load, the fixation is often unstable, which is especially typical for elderly patients with low bone mineral density [2, 3]. To prevent this complication, in recent years, attempts have been made to plasticize the damaged vertebral body with bone cement or bone allograft – deproteinized bone matrix (DBM) in combination with posterior fixation, which provides circular stabilization of the damaged segment. Nevertheless, it is still not clear which method is superior in the treatment of osteoporotic fractures. Several studies [4, 5] have reported satisfactory results of posterior stabilization combined with vertebroplasty to restore vertebral body height and reduce pain, which is even recommended as an alternative to anterior stabilization [6, 7]. However, the most common complication of vertebroplasty (migration of bone cement into the venous system and spinal canal) can cause thromboembolic complications and compression of neural structures [8, 9]. This restricts its application to vertebral body burst fractures. Osteoplasty of the injured vertebral body with posterior fixation is also used [10, 11]. The number of studies directly comparing these methods is small, and the evidence is insufficient. It is also important that there is no clear understanding of the factors that influence the loss of correction and recurrence of kyphotic deformity in patients with osteoporosis.

The objective is to perform a comparative analysis of hybrid stabilization methods (transpedicular fixation combined with cement plasty of injured vertebral body and transpedicular fixation combined with osteoplasty) in the treatment of vertebral body fractures associated with osteoporosis.

Material and Methods

The tasks of the retrospective study included the analysis of hybrid stabilization methods and the identification of possible predictors of incomplete correction of kyphotic deformity and recurrence of local kyphosis.

Inclusion criteria: uncomplicated complete and incomplete burst fractures (types A3, A4 according to AOSpine) of the thoracolumbar vertebral bodies (T10–L2) associated with osteoporosis of the spine with a T-score of -2.5 and lower according to densitometry; absence of bone-seeking therapy before surgery and in the postoperative period with a follow-up period of at least 12 months. Exclusion criteria: complicated spinal injuries and secondary osteoporosis.

Patients

In 2016–2021, a total of 2,351 patients were operated on at the Spinal Pathology Department of the Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan. A total of 197 patients were diagnosed with osteoporosis, including 171 with incomplete and complete burst fractures and 149 with a thoracolumbar level of injury. From this number, 74 patients who underwent hybrid stabilization were chosen for the study: in 25 cases – posterior stabilization in combination with cement plasty of the injured vertebral body (Group 1), and in 49 cases – posterior stabilization in combination with osteoplasty (Group 2). The average time from the moment of injury to surgery was 15 ± 7 days. Additional cement augmentation of the screws in the groups was not performed.

Techniques

The magnitude of kyphosis correction (according to the Cobb) and that of postoperative kyphotic deformity were assessed. The correction was considered incomplete, if it was more than 5°. Recurrence of deformity was estimated at 4, 6, 12 months. The deformity was assumed to be recurrent if it increased by more than 5° throughout the postoperative follow-up (the error in the accuracy of X-ray measurements of intersegmental relations is 5°). The extent of transpedicular fixation (3–4 segments) was assessed. Subjective assessment of patients' condition and sagittal balance parameters was not taken into account.

Statistical analysis

Descriptive statistics of continuous indicators were calculated as median; for binary indicators, the number of cases in percent [95 % confidence interval of percent] was calculated by the Wilson formula. Normality was checked by Shapiro – Wilk test; Mann – Whitney nonparametric unpaired U test was used between the groups; the displacement of distributions was calculated with the construction of a 95 % confidence interval for the displacement. Predictors of insufficient correction and loss of kyphosis correction were determined by constructing logistic regression models. Pairwise numerical associations were defined by the construction of single-factor models; and multiple numerical associations (predictors) – by multifactor models. Statistical hypotheses were tested at a critical significance level of $p = 0.05$, that is, the difference was considered statistically significant at $p < 0.05$.

Results

There was no statistical difference between the groups in age (64.36 ± 6.74 years and 67.08 ± 8.93 years, respectively), the value of the T-score (-3.36 ± 0.51 and -3.18 ± 0.59) and the initial kyphotic deformity (15.76° ± 12.27° and 10.10° ± 7.28°).

According to the injury type (A3 : A4), the distribution in Group 1 was 24.0 : 76.0 %, in Group 2 – 53.1 : 46.9 %. The difference in the kyphosis magnitude after surgery and in the analyzed periods of postoperative follow-up between the groups was not statistically identified (Table 1), as in the magnitude of the deformity correction ($p = 0.590$).

During the analysis, it was found that the surgical method did not significantly affect either the incomplete correction ($p = 0.251$) or the recurrence of the deformity ($p = 0.034$) at all times of follow-up. There was no effect on these criteria of the injury morphology and the length of the posterior instrumentation (1.01 [0.63; 1.82]; $p = 0.248$ with incomplete correction and 1.41 [0.86; 2.83]; $p = 0.240$ with recurrent deformity). In the logistic regression model, a slight influence of the T-score and the extent of fixation was observed (Pearson's correlation coefficient 0.15).

Incomplete deformity correction is affected by the injury level (T12 vertebra) as well as the level of the T-score, and the latter is significant up to 6 months after surgery (Table 2). After this period, the severity of osteoporosis does not affect the recurrence of kyphotic deformity, probably due to the consolidation of fractures.

The construction of multifactorial logistic regression models (Tables 3, 4) demonstrated that injury at the level of the T12 vertebra raises the chances of recurrence of kyphosis in the postoperative period by three times. The magnitude of initial kyphosis is significantly affected if it is greater than 10°. The type of fracture (complete burst) slightly enhances the chances of recurrence. Nevertheless, it is statistically insignificant. It was observed that the value of the T-score with complete deformity correction does not affect the formation of a recurrence of kyphosis during the entire postoperative period.

Fig. 1 and 2 show clinical examples.

Discussion

The purpose of surgical treatment for fractured vertebrae associated with osteoporosis is not only to correct the kyphotic deformity and reduce the pain syndrome in the elderly, but also to prevent possible adverse effects. According to the literature sources of recent years, this aim is achieved through the use of minimally invasive surgical techniques, in particular hybrid stabilization, which in the classical version is a transpedicular fixation in combination with vertebroplasty. Nevertheless, some problems associated with the use of bone cement force researchers to resort to trivial techniques.

For example, Li et al. [10] show the treatment outcomes of burst fractures associated with osteoporosis by performing osteoplasty of the injured vertebral body under posterior fixation conditions. After 3 months of postoperative follow-up, there is a pronounced decrease in pain syndrome, including with prolonged axial loads. The vertebral body height was restored immediately after the surgery. No decrease was observed after 3 months. Also, infectious and neurological complications were not observed, which in total suggests that elderly patients tolerate such interventions well.

In turn, Qin et al. [11] point out that implantation of bone tissue into the vertebral body improves the stability of the entire structure and reduces the pain syndrome. The frequency of vertebral height loss in the postoperative period, beginning from the 6th month, the recurrence of local kyphosis and instru-

mentation instability were higher during these interventions than with isolated short-segment fixation ($p < 0.05$). Satisfactory outcomes of the technique are also confirmed by biomechanical tests [12].

There was no statistical difference in radiological outcomes in our study when comparing two surgical techniques. All patients had no complications during the entire follow-up period. Statistically significant predictors of the recurrence of local kyphosis and increased pain syndrome are the level of injury (T12 vertebra), the degree of initial kyphotic deformity (more than 10°) and its incomplete correction after surgery, and the value of the T-score according to densitometry. The extent of the transpedicular system has no statistically significant effect on the possibility of kyphosis recurrence. However, it should be noted that the severity of osteoporosis influences the length of the transpedicular system: the more severe osteoporosis is, the more important is extended fixation, as shown in the literature [13, 14].

Despite the absence of any difference between the techniques, it is more appropriate to use osteoplasty with deproteinized bone allograft to eliminate the risks arising from the introduction of bone cement into the vertebral body, as well as due to the influence of the toxicity of bone cement and an augmentation of the osteoresorption area

Table 1

Comparison of the magnitude of kyphosis in groups of patients before the surgery and at follow-up control times

Follow-up period	Vertebroplasty +TPF (n = 25)	Osteoplasty +TPF (n = 49)	Difference (effect size) MED [95 % CI]: SMD [95 % CI]	Mann – Whitney U test; p-level
Before surgery	14 [8; 20] 15.76 ± 12.27	12 [6; 15] 10.10 ± 7.28	psevdo MED [95 % CI]: -4.00 [-8.00; 0.00] SMD [95 % CI]: 0.61 [0.12; 1.10]	0.062
After surgery	1 [0; 5] 1.04 ± 3.17	0 [0; 2] 0.20 ± 1.66	psevdo MED [95 % CI]: -1.00 [-3.00; 0.00] SMD [95%CI]: 0.45 [-0.04; 0.94]	0.115
4 months after surgery	1 [0; 5] 2.12 ± 3.09	0 [0; 5] 0.45 ± 4.52	psevdo MED [95 % CI]: 0 [-3.00; 1.00] SMD [95 % CI]: 0.12 [-0.36; 0.60]	0.533
6 months after surgery	1 [0; 6] 2.44 ± 3.38	1 [0; 6] 1.92 ± 6.62	psevdo MED [95 % CI]: 0.00 [-3.00; 1.00] SMD [95 % CI]: 0.09 [-0.39; 0.57]	0.815
12 months after surgery	2 [0; 6] 2.00 ± 4.17	2 [0; 6] 2.27 ± 6.88	psevdo MED [95 % CI]: 0.00 [-3.00; 2.00] SMD [95 % CI]: 0.12 [-0.36; 0.60]	0.689

TPF – transpedicular fixation; MED – median; SMD – standardized mean difference.

Table 2

Logistic regression models of incomplete kyphosis correction in all patients

Covariants	Single-factor models		Multifactor models	
	OR [95 % CI]	p	OR [95 % CI]	p
T12 level	5.96 [1.48; 30.10]	0.016	5.01 [1.20; 26.01]	0.035
Initial kyphosis more than 10°	7.46 [1.29; 141.63]	0.064	6.05 [0.98; 117.13]	0.103
T-score	2.42 [0.79; 7.72]	0.116	–	–
Fixation length	2,95 [0,38; 16,50]	0,238	–	–

Table 3

Logistic regression models of kyphosis recurrence at 4, 6, 12 months after surgery with complete deformity correction in all patients

Covariants	Single-factor models		Multifactor optimal model	
	OR [95 % CI]	p	OR [95 % CI]	p
Initial kyphosis more than 10°	12.16 [2.21; 227.87]	0.019	17.48 [2.59; 375.46]	0.015
T12 level	3.37 [1.03; 11.68]	0.047	3.31 [0.82; 15.35]	0.102
T-score	0.48 [0.13; 1.43]	0.221	0.18 [0.03; 0.77]	0.036

Table 4
Logistic regression models of kyphosis recurrence at 4, 6, 12 months after surgery with incomplete deformity correction in all patients

Covariants	Single-factor models		Multifactor optimal model	
	OR [95 % CI]	p	OR [95 % CI]	p
T-score	0.31 [0.08; 1.00]	0.071	0.33 [0.08; 1.10]	0.102
Kyphosis more than 10° after surgery	2.17 [0.66; 8.54]	0.227	3.08 [0.85; 13.48]	0.104
T12 level	1.40 [0.42; 4.48]	0.570	–	–

at the border of the bone-cement contact. This is especially true for complete burst fractures. The question of whether sagittal profile disruption is a predictor of post-traumatic deformity recurrence in osteoporotic fractures remains open, which may prompt further research.

Conclusion

In the course of the study, there was no statistical difference detected in radiological outcomes between the techniques of cement vertebroplasty and osteoplasty in combination with posterior stabilization in the treatment of burst fractures associated with osteoporosis. There was no effect of the technique on the loss of correction in the long-term period either. Nevertheless, the presence of such predictors as injury to the T12 vertebra, the magnitude of initial kyphotic deformity, and the persistence of residual kyphosis of more than 10° after surgery increase the risk of recurrence of kyphotic deformity with both techniques.

Study limitations: the small patient sampling did not allow for long-term analysis of the effect of sagittal imbalance on outcomes, so this issue was not included in the study objectives.

The study had no sponsors. The authors declare that they have no conflict of interest.
The study was approved by the institution's local ethics committee.
All authors contributed significantly to the research and preparation of the article, read and approved the final version before publication.

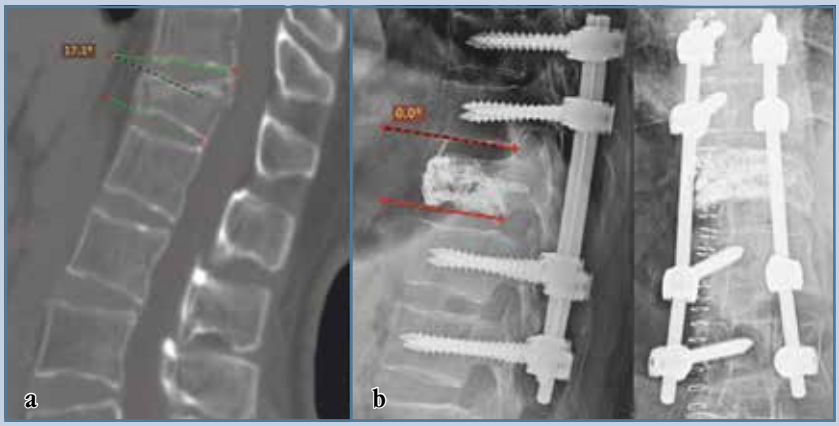

Fig. 1
CT and radiographs of a 55-year-old female patient with a complete burst fracture of the T12 vertebral body: **a** – post-traumatic kyphosis at the level of T11–T12 – 17°; spinal osteoporosis (T-score -3.9); **b** – condition after cement vertebroplasty of the body of the T12 vertebra, extended posterior stabilization, correction of kyphosis

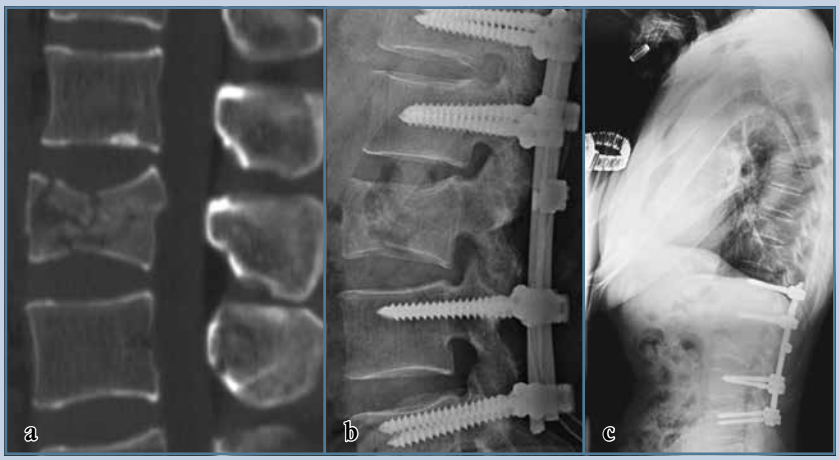

Fig. 2
CT and radiographs of a 64-year-old female patient with a complete burst fracture of the L2 vertebral body, spinal osteoporosis (T-score -3.1): **a** – before the surgery; **b** – after the osteoplasty of L2 vertebra with a bone allograft, extended posterior stabilization; **c** – 12 months after the surgery

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